Investigations on pine and oak wood.[3]

This series of investigations by Dr. R. Hartig, begun in 1891 and completed early in the present year are a continuation of investigations begun many years ago; and they are to be followed by others by the same author dealing especially with the influences exerted by the soil in which trees grow, and the results obtained by growing trees in masses and in the open. While the investigations were conducted in accordance with scientific methods nothing that will be of value to the practical forester has been omitted.

PINE.—The trees studied were grouped in five or six classes according to diameter at a given height above the ground. For convenience periods of ten or twenty years are taken as units, each designated as a growth period. Classes one, two, and three attained the maximum annual growth in height in the growth period between thirty and forty years; class four a decade earlier; class five continued its maximum annual growth nearly twenty years, i. e., from twenty to forty. Class six did not reach its greatest growth until the two periods between forty and sixty years. The last tree had early fallen behind the others in growth and was consequently overshadowed by them. By the time the forest was forty years old class six was so completely shaded that a rapid growth in height became necessary in order to obtain sunlight.

In a pine tree one hundred years old five of the annual rings of wood, within the last twenty years of growth, did not extend down to a point 1.3 meters above the ground; four were lacking at a point 3.5 meters above the ground; two at 5.5 meters; and one at 7.7 meters. Two of these short rings were formed more than ten years before the tree died. This indicates an exceedingly interesting physiological fact, namely that the cambium may remain inactive for years without losing its power of cell-division.

As a result of these and some earlier investigations the author derives his theory for the formation of the annual ring. Briefly stated it is as follows: The wood formed in the early part of the season is composed chiefly of large vessels with wide lumina. These are designated as conducting organs. It is along these that the larger portion of the transpiration stream passes. When a sufficient quantity of conducting tis-

[3] ROBERT HARTIG.—Forstlich-naturwissenschaftliche Zeitschrift. **1**: 129, 169, 209. 1892.—**2**: 49, 249, 289. 1893.—**3**: 1, 49, 172, 193. 1894.

sue has been formed wood composed of smaller, much thicker walled cells is produced.

In pine forests of recent growth the maximum thickness of the annual ring is found in the first ten years. In trees grown in the primeval forest, the maximum thickness is not reached until the one hundredth year; sometimes as late as the one hundred fiftieth or sixtieth. The thickness of the annual ring is greater in the upper part of the trunk than in the lower, excepting in trees grown in the open. This is due to two reasons: First, the action of the cambium begins three or four weeks earlier in the tops of closely growing pines than in the lower parts of the trunks, thus producing a greater number of cells above than below in the season; second, as the nourishment of the tree must pass from the top to all lower parts, the upper part is at all times supplied with a greater quantity of material for cell formation than the lower.

The quality of timber is found to differ very greatly, not only in different trees grown under apparently the same external conditions, but also in different parts of the same tree.

Of the timber from recently grown pine forests, the first formed is the poorest, the value increasing with each year's production. Pine trees growing in the shade, having comparatively little transpiration, and with growth beginning late in the season, have valuable wood from the beginning. Trees grown well up the sides of mountains or in wet localities have the best wood formed early.

The amount of water present decreases from the outer part of the tree to the inner, with a sudden falling off, in passing from sap-wood to heart-wood. The relative amount of alburnum to duramen is not always the same on different sides of the same tree. There may be a difference of as much as ten annual rings. The percentage of shrinkage in heart-wood of pine is much less than that of sap-wood. In comparison it is interesting to note that in the beech the percentage of shrinkage is the same for the old and young trees, for sap-wood and heart-wood, while in the oak the shrinkage is much greater in the sap-wood. The smaller amount of shrinkage in the heart-wood of pine and oak is due to the deposition of the material which characterizes heart-wood, in the micellar interstices of its cell walls.

A difference in size of trees of the same age is very closely related to the difference in size of the elements composing them.

OAK.—The trees used in the work upon oak wood were felled at different times during the season, beginning May 2. At this time, though swelling of the buds was not perceptible, the first large vessels were fully formed. The activity of the cambium had doubtless begun in the last week in April. Activity in this tree had begun in all aerial parts at the same time. On the 6th of June the cambium of the roots one-half meter from the stem was still dormant. By the 21st of June the annual growth of stem was half completed. When compared with the preceding annual ring the thickness of the forming ring was found to vary from .45 to .72. On the 19th of August the formation of wood at the base of the trunk had ceased, in the upper part of the trunk the cells were still thinwalled and unlignified, while in the smaller branches cell-formation was still going on. By the 5th of September the formation of wood had ceased in all parts of the tree. The time required for the formation of the annual ring is thus shown to be a little more than four months, extending from last third of April to the last of August. In this connection the author states that in red beech and pine growth does not begin until about four weeks later, being completed in the pine as early as Aug. 10th, and in the beech but little later, making the time required for formation of an annual ring in the beech and pine about two and a half months.

At the time that shoots and leaves are developing, a complete transformation of the starch in the smaller branches takes place. In the older parts of the tree the starch of the bark (phloem and cortex) is first changed for the nourishment of the cambium. At the beginning of June for a short time all starch disappears from the sap-wood. This disappearance has already begun in the upper part of the trunk by the middle of May. The disappearance of starch progresses inward and downward, and is completed by the 6th of June, only the starch of the roots remaining unchanged. By the middle of June the storing of food in the form of starch has begun in the outer sap-wood layers of the trunk and of branches a few years old. The 1–3-year-old twigs are still without starch. The newer sap-wood is still empty. The youngest wood-ring, on the contrary, shows some starch in the vicinity of the large vessels. Traces of it are also found in the phloem. At the beginning of July all parts of the tree are well stocked with reserve starch. Its accumulation in the phloem has been more rapid in the upper part of the tree than in the lower. From the beginning of August to the middle starch is entirely wanting in the phloem of the branches. In the phloem of the stem only traces of it are found in the outer part. It is assumed that the starch has been withdrawn from the phloem a second time to be used in the growth of the phloem itself. Not until the beginning of September has the accumulation of reserve food begun again in the phloem, and then only in the lower part of the stem. As late as the 30th of September the bark of the 1–2-year-old twigs is still free of starch, although it is abundantly supplied with it by the end of October. In December the starch has been changed into sugar and oil.

The amount of water in oak wood taken from different parts of the same tree varies considerably. It is very abundant, as a rule, in the outer layers of sap-wood; less so in the inner layers; while the outer portion of the heart-wood is comparatively poor in water with a constantly increasing amount as one nears the center of the tree. Taken as a whole the heart-wood usually contains a larger percentage of water than the sap-wood. The wood of the root-shaft contains more water than that of any other part of the tree. The small roots, however, seem to be poor in water. There is a decrease in the amount of water present in passing from the base of the tree toward the crown. This decrease continues in very old trees to the ends of the twigs. In young trees the diminution is continued to the upper end of bole, but from here to the extremities of the twigs, there is a constant increase. In perfectly air-dry oak wood, to every 100 volumes of the wood substance there are 19 to 20 volumes of imbibition water.

In reviewing the results of his investigations, the author calls attention to one fact of especial interest from a physiological standpoint; the adaptation of the anatomical structure of the wood of trees to their needs as produced by external conditions. The smaller roots, which either do not perform any mechanical function for the tree, or if so, only to a limited degree, contain no trace of mechanical tissue. The larger roots and root-shaft, on the contrary, have so much mechanical tissue that they furnish well nigh the strongest wood of the tree. In these places strong wood is necessary for resisting the force of winds. If for any reason the transpiration of a tree is large in proportion to its conducting tissue, the wood of the tree will be composed largely of conducting and storage tissue; on the other hand, if the amount of transpiration is limited to any considerable degree, less conducting tissue will be required and the tree will have at its disposal a larger quantity of plastic material from which to produce mechanical tissue.—L. S. CHENEY.

Adaptation of African plants to climate.[4]

After some introductory remarks upon the highly interesting flora of Cape Colony, the author describes the different ways in which the plants are adapted to the climate. The variety of arrangements for this purpose is very great and may be considered from different points of view. The evaporation is prevented by reduction of the leaves, either by the development of small leaf-blades, or by transferring their function to green stems. Stapelia, Euphorbia and the imported Opuntia illustrate the last case, while small or narrow leaves are very common, for instance in Bruniaceæ, many Compositæ, and others. Some other plants show the surface of the leaves impregnated with substances that are impermeable to water, and this is to be observed in Aloe, Protea, Myrica and several others. The cuticle, or a cover of wax or silica, forms the protective medium in these plants.

A covering of hairs is also very common, by which the communication between the atmosphere and the air within becomes greatly impeded. Leucadendron, Helichrysum, several Leguminosæ, and Proteaceæ are protected in this way.

Secreted mineral substances may also form a protecting layer over the whole leaf as in Tamarix, or only over the depressions in which the stomata are situated, as in Statice, Vogelia, and other Plumbagineæ.

Such arrangements as the placing of the stomata in depressions or in grooves of leaves and stems, or under the reflexed edges of the leaves are also common in this vegetation.

Eucalyptus globulus and Protea grandiflora illustrate the case in which the leaves assume the most favorable position towards the sun.

There are also plants which possess reservoirs in their stems, rhizomes, or leaves. Such plants are the delicate herb, Ele-

[4] MARLOTH, R.—Some adaptations of South African plants to the climate. Trans. South African Phil. Soc. **6**: 31.